Introduction

Chapter Background

A strong national consensus supports the public funding of academic research, and although the Federal Government plays a diminishing role, it still provides close to 60 percent of the financial resources. More than half of academic research and development (R&D) funds go to the life sciences, and this share increased during the past quarter century, raising concern about whether the distribution of funds is appropriately balanced. The number of academic institutions receiving Federal support for R&D activities increased dramatically during the past several decades, expanding the base of the academic R&D enterprise. Recently, however, this number began to decline. The Federal Government plays a minor role in providing direct support to universities and colleges for construction of their research facilities. Nevertheless, the amount of academic science and engineering (S&E) research space grew continuously over the past decade. In contrast, the Federal Government accounted for almost 60 percent of direct expenditures of current funds for academic research equipment, but the percentage of total annual R&D expenditures devoted to such equipment declined noticeably during the past decade. Doctoral S&E faculty in universities and colleges play a critical role in ensuring an adequate, diverse, and well-trained supply of S&E personnel for all sectors of the economy. Until recently, positive outcomes and impacts of R&D were taken for granted; however, the system has begun to face demands that it devise means and measures to account for specific Federal R&D investments.

This chapter addresses key issues of the academic R&D enterprise, such as the importance of a Federal role in supporting academic research; the appropriate balance of funding across S&E disciplines; the breadth and strength of the academic base of the nation's S&E and R&D enterprise; the adequacy of research facilities and instrumentation at universities and colleges; the role of doctoral S&E faculty, including both their teaching and their research responsibilities; and accountability requirements, including measuring outputs and larger social outcomes.

Chapter Organization

The first section of this chapter discusses trends in the financial resources provided for academic R&D, including allocations across both academic institutions and S&E fields. Because the Federal Government has been the primary source of support for academic R&D for more than half a century, the importance of selected agencies in supporting individual fields is explored in detail. This section also presents data on changes in the number of academic institutions that receive Federal R&D support and then examines the status of two key elements of university research activities: facilities and instrumentation.

The next section discusses trends in the employment of academic doctoral scientists and engineers and examines their activities and demographic characteristics. The discussion of employment trends focuses on full-time faculty, postdoctorates, graduate students, and other positions. Differences between the nation's largest research universities and other academic institutions are considered, as are shifts in the faculty age structure. The involvement of women and underrepresented minorities, including Asians/Pacific Islanders, is also examined. Attention is given to participation in research by academic doctoral scientists and engineers, the relative balance between teaching and research, and Federal support for research. Selected demographic characteristics of recent doctorate-holders entering academic employment are reviewed.

The chapter concludes with an assessment of two research outputs: scientific and technical articles in a set of journals covered by the Science Citation Index (SCI) and the Social Science Citation Index (SSCI) and patents issued to U.S. universities. (A third major output of academic R&D, educated and trained personnel, is discussed in the preceding section of this chapter and in chapter 2). This section looks specifically at the volume of research (article counts), collaboration in the conduct of research (joint authorship), use in subsequent scientific activity (citation patterns), and use beyond science (citations to the literature on patent applications). It concludes with a discussion of academic patenting and some returns to academic institutions from their patents and licenses.

Financial Resources for Academic R&D

Academic R&D is a significant part of the national R&D enterprise.[1] Enabling U.S. academic researchers to carry out world-class research requires adequate financial support as well as excellent research facilities and high-quality research equipment. Consequently, assessing how well the academic R&D sector is doing, the challenges it faces, and how it is responding to those challenges requires data and information on a number of important issues relating to the financing of academic R&D, including:

- the level and stability of overall funding,
- the sources of funding and changes in their relative importance,
- the distribution of funding among the different R&D activities (basic research, applied research, and development),
- the balance of funding among S&E fields and subfields (or fine fields),
- the distribution of funding among various types of academic R&D performers and the extent of their participation,

[1] Federally funded research and development centers (FFRDCs) associated with universities are tallied separately and are examined in greater detail in chapter 4. FFRDCs and other national laboratories (including Federal intramural laboratories) also play an important role in academic research and education, providing research opportunities for both students and faculty at academic institutions.

- the changing role of the Federal Government as a supporter of academic R&D and the particular roles of the major Federal agencies funding this sector, and
- the state of the physical infrastructure (research facilities and equipment) that is a necessary input to the sector's success.

Individually and in combination, these issues influence the evolution of the academic R&D enterprise and therefore are the focus of this section. For a discussion of the nature of the data used in this section, see the sidebar, "Data Sources for Financial Resources for Academic R&D."

Academic R&D Within the National R&D Enterprise

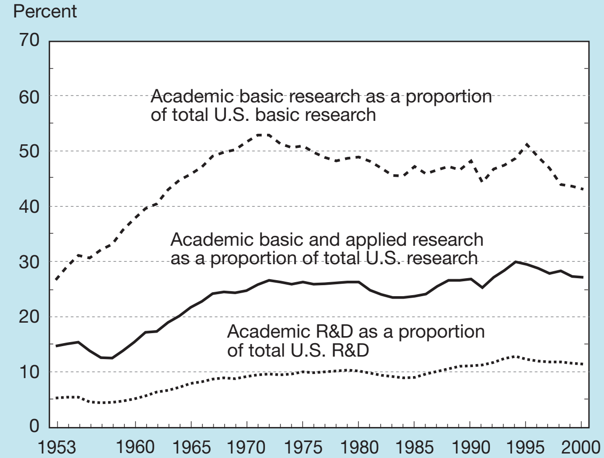
The continuing importance of academia to the nation's overall R&D effort is well accepted today.[2] This is especially true for its contribution to the generation of new knowledge through basic research. During the 1990s, academia accounted for slightly less than half of the basic research performed in the United States.

In 2000, U.S. academic institutions spent an estimated $30 billion, or $28 billion in constant 1996 dollars, on R&D.[3] This was the 26th consecutive year in which constant-dollar spending increased from the previous year. Academia's role as an R&D performer has increased steadily during the past half century, rising from about 5 percent of all R&D performed in the United States in 1953 to almost 11 percent in 2000. (See figure 5-1.) However, since 1994, the sector's performance share has dipped slightly from its high of almost 13 percent. The decline in the academic share is the result of rapid growth in industrial R&D performance. See the section "Growth" below. For a comparison with other industrial countries, see the sidebar, "Comparisons of International Academic R&D Spending."

Character of Work

Academic R&D activities are concentrated at the research (basic and applied) end of the R&D spectrum and do not include much development activity.[4] For academic R&D expenditures in 2000, an estimated 93 percent went for research (69 percent for basic and 24 percent for applied) and 7 percent for development. (See figure 5-2.) From the perspective of national research, as opposed to national R&D, academic institutions accounted for an estimated 27 percent of the U.S. total in 2000. The academic share of research almost doubled, from about 14 percent of the U.S. total in the 1950s to around 26 percent in the first half of the 1970s. (See figure 5-1.) It has since fluctuated between 23 and 30 percent. In terms of basic research alone, the academic sector is the country's largest performer, currently accounting for an estimated 43 per-

Figure 5-1.
Academic R&D, basic and applied research, and basic research as a proportion of U.S. totals: 1953–2000

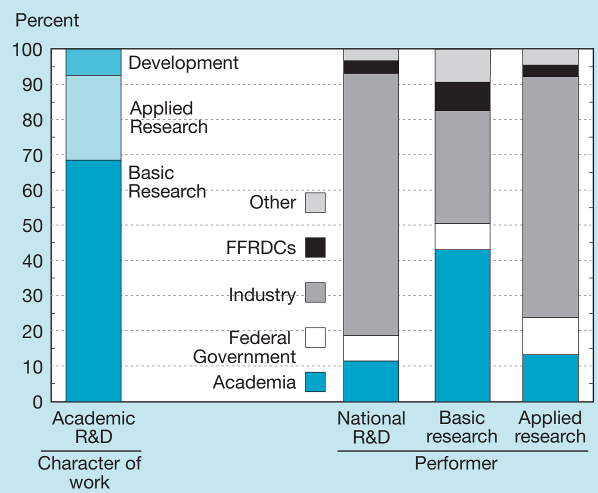


NOTE: Data for 1999 and 2000 are preliminary.

See appendix tables 4-3, 4-7, and 4-11.

Science & Engineering Indicators – 2002

Figure 5-2.
Academic R&D expenditures, by character of work, and national R&D expenditures, by performer and character of work: 2000



FFRDC = Federally Funded Research and Development Center

NOTE: Data are preliminary.

See appendix tables 4-3, 4-7, 4-11 and 5-1.

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[2] For more detailed information on national R&D expenditures, see "R&D Performance in the United States " in chapter 4.

[3] For this discussion, an academic institution is generally defined as an institution that has a doctoral program in science or engineering, is a historically black college or university that expends any amount of separately budgeted R&D in S&E, or is some other institution that spends at least $150,000 for separately budgeted R&D in S&E.

[4] Despite this delineation, the term "R&D" (rather than just "research") is primarily used throughout this discussion because data collected on academic R&D often do not differentiate between research and development. Moreover, it is often difficult to make clear distinctions among basic research, applied research, and development. For the definitions used in NSF resource surveys and a fuller discussion of these concepts, see chapter 4.

Data Sources for Financial Resources for Academic R&D

The data used to describe financial resources for academic R&D are derived from several National Science Foundation (NSF) surveys and one National Center for Education Statistics (NCES) survey. These surveys use similar but not always identical definitions, and the nature of the respondents also differs across the surveys. NSF's four main surveys involving academic R&D are as follows:

1. the Survey of Federal Funds for Research and Development,
2. the Survey of Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions,
3. the Survey of Research and Development Expenditures at Universities and Colleges, and
4. the Survey of Scientific and Engineering Research Facilities.

The NCES survey used is the Integrated Postsecondary Education Data System (IPEDS) Finance Survey. The first two NSF surveys collect data from Federal agencies, whereas the last two NSF surveys and the NCES survey collect data directly from universities and colleges.*

Data presented in the context section, "Academic R&D Within the National Enterprise," are derived from *National Patterns of R&D Resources* (National Science Foundation (NSF) 2000), a report that aggregates NSF survey data on the various sectors of the U.S. economy so that the components of the overall R&D effort are placed in a national context. These data are reported on a calendar-year basis, and the data for 1999 and 2000 are preliminary. Data in subsequent sections are reported on an academic or fiscal-year basis and therefore differ from those reported in this section. Data on major funding sources, funding by institution type, distribution of R&D funds across academic institutions, and expenditures by field and funding source are from the Survey of Research and Development Expenditures at Universities and Colleges. For various methodological reasons, parallel data by field from the NSF Survey of Federal Funds for Research and Development do not necessarily match these numbers.

The data in the section "Emphasis on Research at Universities and Colleges" are drawn from the NCES IPEDS finance survey. Although the definition of research used in this survey is similar to that used in NSF surveys, the data collected include fields other than S&E and do not include many of the indirect costs associated with research; thus, they are not comparable with other data presented in this chapter. The IPEDS Finance Survey reports indirect costs as part of lump sums in other separate expenditure categories, such as academic support, institutional support, and operation and maintenance of plant, rather than distributing these costs to the research, instruction, and public service functions. Data for 1996 were the most recent available at the time this report was prepared. (For more information about indirect costs, see the sidebar, "Recent Developments on the Indirect Cost Front," later in this chapter.)

The data in the "Federal Support of Academic R&D" section come primarily from NSF's Survey of Federal Funds for Research and Development. This survey collects data on R&D obligations from about 30 Federal agencies. Data for fiscal year (FY) 2000 and FY 2001 are preliminary estimates. The amounts reported for FY 2000 reflect congressional appropriation action as of the third quarter of FY 2000, the period in which the last survey was conducted. Data for FY 2001 represent administration budget proposals that had not been acted on. Data on Federal obligations by S&E field are available only for FY 1999, as they are not estimated and refer only to research (basic and applied) rather than to research plus development.

The data in the section "Spreading Institutional Base of Federally Funded Academic R&D" are drawn from NSF's Survey of Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions. This survey collects data on Federal R&D obligations to individual U.S. universities and colleges from the approximately 18 Federal agencies that account for virtually all such obligations. For various methodological reasons, data reported in this survey do not necessarily match those reported in the Survey of Research and Development Expenditures at Universities and Colleges.

Data on facilities are taken from the Survey of Scientific and Engineering Research Facilities. Data on research equipment are taken from the Survey of Research and Development Expenditures at Universities and Colleges. Although terms are defined specifically in each survey, in general, facilities expenditures are classified as "capital" funds, are fixed items such as buildings, often cost millions of dollars, and are not included within R&D expenditures as reported here. Equipment and instruments (the terms are used interchangeably) are generally movable, purchased with current funds, and included within R&D expenditures. Because the categories are not mutually exclusive, some large instrument systems could be classified as either facilities or equipment. Expenditures on research equipment are limited to current funds and do not include expenditures for instructional equipment. Current funds, as opposed to capital funds, are those in the yearly operating budget for ongoing activities. Generally, academic institutions keep separate accounts for current and capital funds.

* For descriptions of the methodologies of the NSF surveys, see NSF 1995a and 1995b and the Division of Science Resources Statistics website: <http://www.nsf.gov/sbe/srs/stats.htm>. Information about the NCES survey is available at the NCES website: <http://www.ed.gov/NCES>.

cent of the national total. Between 1953 and 1972, the academic sector's basic research performance grew steadily, increasing from about one-quarter to slightly more than one-half of the national total. It has since fluctuated at between 43 and 51 percent of the national total.

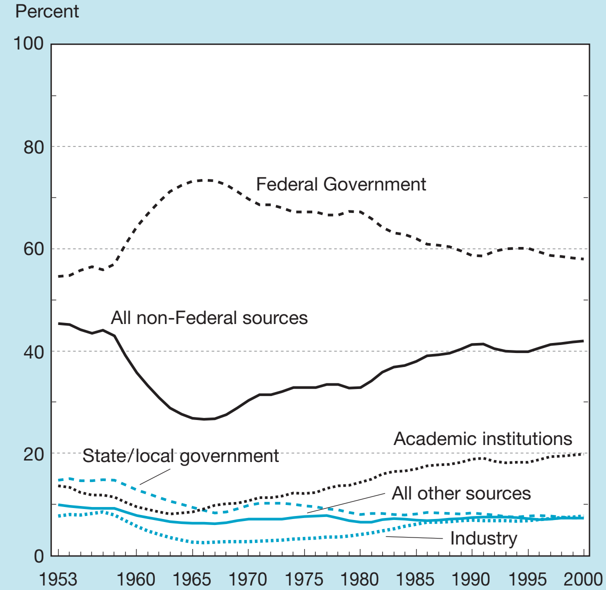
Growth

Over the course of the past half century (1953 to 2000), the average annual R&D growth rate (in constant 1996 dollars) of the academic sector has been higher than that of any other R&D-performing sector at 6.6 percent compared with about 5.8 percent for other nonprofit entities, 5.0 percent for industry, 3.8 for federally funded research and development centers (FFRDCs), and 2.6 percent for the Federal Government. (See figure 5-3 and appendix table 4-4 for time series data by R&D performing sector.) However, during the second half of the 1990s, average annual R&D growth within industry (an estimated 6.9 percent) was higher than at academic institutions (an estimated 4.1 percent). As a proportion of gross domestic product (GDP), academic R&D rose from 0.07 to 0.30 percent between 1953 and 2000, more than a fourfold increase. (See appendix table 4-1 for GDP time series.)

Major Funding Sources

The academic sector relies on a variety of funding sources for support of its R&D activities. Although the Federal Government continues to provide the majority of funds, its share has declined steadily since reaching a peak of slightly more than 73 percent in 1966. In 2000, the Federal Government accounted for an estimated 58 percent of the funding for R&D performed in academic institutions, its lowest share since the late 1950s. (See figure 5-4.) The Federal sector primarily supports basic research; 74 percent of its 2000 funding went to basic research versus 26 percent to applied R&D. (See appendix table 5-1.) Non-Federal sources also are used predominantly for basic research; 62 percent of its 2000 funding went to basic research versus 38 percent to applied R&D).

Figure 5-4.
Sources of academic R&D funding: 1953–2000



NOTE: Data for 1999 and 2000 are preliminary.

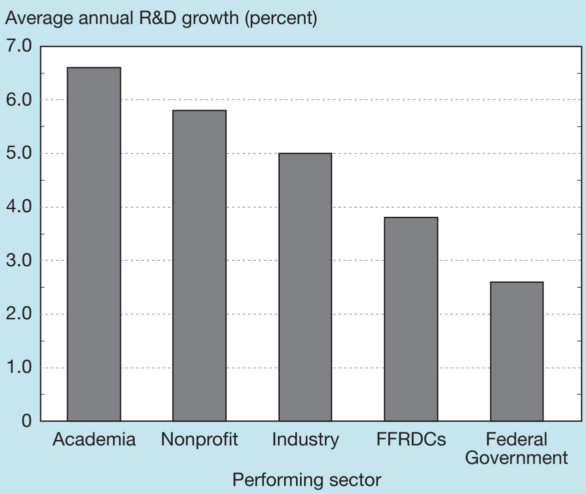
See appendix table 5-2. *Science & Engineering Indicators – 2002*

Federal support of academic R&D is discussed in detail later in this section; the following list summarizes the contributions of other sectors to academic R&D:[5]

- **Institutional funds.** In 2000, institutional funds from universities and colleges constituted the second largest source of funding for academic R&D, accounting for an estimated 20 percent, the highest level during the past half century. Institutional funds encompass three categories: separately budgeted funds from unrestricted sources that an academic institution spends on R&D, unreimbursed indirect costs associated with externally funded R&D projects, and mandatory and voluntary cost sharing on Federal and other grants. For more detailed discussions of both indirect costs and the composition of institutional funds, see the sidebars "The Composition of Institutional Academic R&D Funds" and "Recent Developments on the Indirect Cost Front."

The share of support represented by institutional funds has been increasing steadily since the early 1960s, except for a brief downturn in the early 1990s. Institutional R&D funds

Figure 5-3.
Average annual R&D growth, by performing sector: 1953–2000



FFRDC = Federally Funded Research and Development Center

See appendix table 4-4. *Science & Engineering Indicators – 2002*

[5] The academic R&D funding reported here includes only separately budgeted R&D and institutions' estimates of unreimbursed indirect costs associated with externally funded R&D projects, including mandatory and voluntary cost sharing. It does not include departmental research and thus will exclude funds, notably for faculty salaries, in cases where research activities are not separately budgeted.

Comparisons of International Academic R&D Spending

Countries differ in the proportion of their research and development that is performed at institutions of higher education. Among the G-7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) R&D performed in the academic sector, as a proportion of total R&D performance, varied between 12 percent in the United States and 25 percent in Italy. In Russia, only 5 percent of R&D was performed in academic institutions. (See text table 5-1.)

A number of factors may account for the differences in the role academia plays in the performance of R&D from country to country. The distribution of a country's R&D expenditures among basic research, applied research, and development affects the share performed by higher education. Because the academic sector primarily carries out research (generally basic) rather than development activities, countries in which development activities take greater prominence rely less on the academic sector for overall R&D performance. The importance of other sectors in R&D performance also affects the academic sector's share. Among the G-7 countries, the United States has the highest share of R&D performed by industry.* Institutional and cultural factors such as the role and extent of independent research institutions, national laboratories, and government-funded or -operated research centers, probably also affect the academic sector's share.

Text table 5-1.
Academic R&D as percentage of total R&D performance: 1998 or 1999

United States	12
Canada	24
France	18
Germany	17
Italy	25
Japan	15
Russia	5
United Kingdom	20

See appendix table 4-42.

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Finally, different accounting conventions among countries may account for some of the differences reported. The national totals for academic R&D for Europe, Canada, and Japan include the research components of general university funds (GUF) provided as block grants to the academic sector by all levels of government. Therefore, at least conceptually, the totals include academia's separately budgeted research and research undertaken as part of university departmental research activities. In the United States, the Federal Government generally does not provide research support through a GUF equivalent, preferring instead to support specific, separately budgeted R&D projects. On the other hand, a fair amount of state government funding probably does support departmental research at U.S. public universities. Universities generally do not maintain data on departmental research, which is considered an integral part of instruction programs. U.S. totals thus may be underestimated relative to the academic R&D efforts reported for other countries.

*See "International R&D by Performer, Source, and Character of Work" in chapter 4 for more detailed information, including data on the sources of funding for academic R&D in different countries.

may be derived from (1) general-purpose state or local government appropriations (particularly for public institutions) or Federal appropriations; (2) general-purpose grants from industry, foundations, or other outside sources; (3) tuition and fees; (4) endowment income; and (5) unrestricted gifts. Other potential sources of institutional funds are income from patents or licenses and income from patient care revenues. See "Patents Awarded to U.S. Universities" later in this chapter for a discussion of patent and licensing income.

- **State and local government funds.** State and local governments provided an estimated 7 percent of academic R&D funding in 2000. They played a larger role during the early 1950s, when they provided about 15 percent of the funding. Since 1980, the state and local share of academic R&D funding has fluctuated between 7 and 8 percent. This share, however, only reflects funds directly targeted to academic R&D activities by the state and local governments. It does not include general-purpose state or local government appropriations that academic institutions designate and use for separately budgeted research or to cover unreimbursed indirect costs.[6] Consequently, the actual contribution of state and local governments to academic R&D is understated, particularly for public institutions.

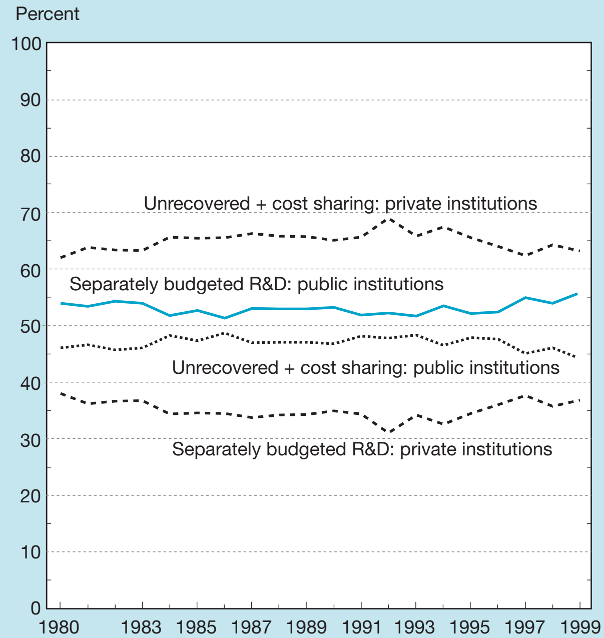
- **Industry funds.** In 2000, industry provided an estimated 8 percent of academic R&D funding. The funds provided for academic R&D by the industrial sector grew faster than funding from any other source during the past three decades, although industrial support still accounts for one of the smallest shares of funding. Industrial funding of academic R&D has never been a major component of industry-funded R&D. During the 1950s, industry's share was actually larger than it is currently, peaking at 8.5 percent in 1957. In 1994, industry's contribution to academic R&D represented 1.5 percent of its total support of R&D compared with 1.4 percent in 1990, 0.9 percent in 1980, 0.6 percent in 1970, and 1.1 percent in 1958. Since 1994, the share

[6] This follows a standard of reporting that assigns funds to the entity that determines how they are to be used rather than to the one that necessarily disburses the funds.

The Composition of Institutional Academic R&D Funds

During the past three decades, institutional funds for academic R&D grew faster than funds from any other sources except industry and faster than any other source during the past five years. (See appendix table 5-2.) In 2000, academic institutions are estimated to have committed a substantial amount of their own resources to R&D: roughly $6 billion, or 20 percent of total academic R&D. In 1999, the share of institutional support for academic R&D at public institutions (24 percent) was greater than at private institutions (9 percent). (See appendix table 5-3.) One possible reason for this large difference in relative support is that public universities and colleges' own funds may include considerable state and local funds not specifically designated for R&D but used for that purpose by the institutions. Throughout the 1980s and 1990s, institutional R&D funds were divided roughly equally between two components: separately budgeted institutional R&D funds and mandatory and voluntary cost sharing plus unreimbursed indirect costs associated with R&D projects financed by external organizations. Institutional funds at public and private universities and colleges differ not only in their importance to the institution but also in their composition. From 60 to 70 percent of private institutions' own funds were designated for unreimbursed indirect costs plus cost sharing compared with 44 to 50 percent of public institutions' own funds. (See figure 5-5.) For information about recent changes in indirect cost policy, see the sidebar, "Recent Developments on the Indirect Cost Front."

Figure 5-5.
Components of institutional R&D expenditures for public and private academic institutions: 1980–99



SOURCE: National Science Foundation, Division of Science Resources Statistics. Survey of Academic Research and Development Expenditures, special tabulations.

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Recent Developments on the Indirect Cost Front

About three-quarters of the Federal investment in academic R&D supports the direct costs of conducting research, that is, those costs that can be directly attributed to a research project. The remainder of the investment reimburses indirect costs. These are general expenses that cannot be associated with specific research projects but pay for things that are used collectively by many research projects at an academic institution. Two major components of indirect costs exist: (1) the construction, maintenance, and operation of facilities used for research and (2) the support of administrative expenses such as financial management, institutional review boards, and environment, health, and safety management. The Office of Management and Budget (OMB) Circular A-21, the document governing indirect cost reimbursement policies, documentation, and accounting practices, refers to these costs as "facility and administrative" (F&A) costs (U.S. Office of Management and Budget (U.S. OMB) 2000). F&A rates are established through negotiations between the Federal Government and individual institutions and are then generally used to determine the F&A reimbursement.

In 1998, Congress, through the National Science Foundation Authorization Act (Public Law 105-207), directed the Office of Science and Technology Policy (OSTP) to address six issues related to the ways universities and colleges recover indirect costs incurred in performing research under Federal grants and contracts:

1. comparison of indirect cost rates across sectors,
2. distribution of rates by spending category,
3. the impact of changes in OMB Circular A-21,
4. the impact of Federal and state law on rates,
5. options to reduce or control the rate of growth of reimbursement rates, and
6. options for creating an indirect cost database.

In July 2000, OSTP produced a report addressing these issues (U.S. Office of Science and Technology Policy (U.S.

OSTP) 2000). In conducting its analyses, OSTP used input from a report that it commissioned from RAND (Goldman et al. 2000), data provided by the Council on Governmental Relations, discussions and data provided by a small group of public and private research universities, discussions with OMB and other Federal agencies, and other unpublished reports. In its analysis of the six major issues raised by Congress, OSTP concluded the following:

1. **Comparison of F&A rates across sectors.** Rates at universities and colleges appear to be slightly lower than those at other types of research institutions, such as Federal laboratories and industrial facilities.

2. **Distribution of F&A rates by spending category.** Negotiated F&A rates have remained stable at approximately 50 percent for at least a decade. The average rates for administration have declined somewhat, although rates for facilities have increased. The decline in the administrative rate can be attributed to the imposition of the administrative cap in 1991; however, the F&A rate often is not an accurate reflection of an institution's actual recovery. (See item 4 below.)

3. **Impact of changes in OMB Circular A-21.** During the 1990s, OMB implemented a number of changes in Circular A-21 to limit the payment of certain costs, to provide clarification for consistent treatment of other costs, and to simplify some administrative procedures. During 1993, the first full year of the 26 percent administrative cap, negotiated administrative rates fell by about 2 percent and have since remained constant. Depreciation/use allowance rates for buildings and equipment have increased gradually from 6 percent in 1988 to approximately 9 percent in 1999, although some of the increase has been offset by reductions in operations and maintenance rates.

4. **Impact of Federal and state laws on F&A rates.** Some Federal statutes and agency policies may limit the amount a university can recover. Moreover, state policies and internal institutional policies may also limit F&A recovery. In addition to the administrative requirements mandated by OMB circulars, universities must also satisfy other Federal, state, and local laws and regulations regarding the conduct of research. These laws and regulations govern practices in many areas, including hazardous waste, occupational safety, animal care, and the protection of human subjects and are associated with real administrative costs that most likely will affect F&A rates for universities that are below the 26 percent cap on administrative costs. Universities whose administrative expenses are already at or above the 26 percent cap may need to provide additional institutional resources for their research activities. See the previous sidebar, "The Composition of Institutional Academic R&D Funds," for further discussion of unreimbursed indirect costs.

5. **Options to reduce or control the rate of growth of Federal F&A reimbursement rates.** If changes were implemented to reduce F&A reimbursement, the resulting shift of costs to universities would be detrimental to the research enterprise by either reducing spending for research and education or being passed on to students through increased tuition rates. In addition, any enactment of the mechanisms to decrease indirect cost recovery that are discussed in the report could result in reduced investments in building and renovating scientific facilities, thus jeopardizing future research capability and the S&E workforce. For the specific options discussed to reduce F&A costs, see U.S. OSTP 2000, appendix B.

6. **Options for creating an F&A database.** Some existing databases capture some F&A data. However, no systematic method by which the Federal Government collects data on F&A rates and costs exists. Therefore, it would be advantageous to create and maintain a database for Federal research F&A data that could track Federal indirect cost rates and reimbursement. Such a database would permit analysis of the impact that changes in policies would have on indirect costs and on the Federal Government, researchers, and research institutions. Creating such a database would require an organization within the government to take responsibility for collecting and analyzing these data. A revision to Circular A-21 in August 2000, required institutions to use a standard format for F&A rate proposals submitted on or after July 1, 2001. Adoption of this standard format might prove useful in facilitating the future development of an F&A database.

In early 2001, OMB issued a memorandum clarifying its treatment of two indirect cost issues—voluntary uncommitted cost sharing and tuition remission costs. For a detailed discussion of the changes, see Gotbaum 2001. Most faculty-organized research effort is either charged directly to the sponsor or is considered mandatory or voluntary cost sharing and captured in the accounting system. Voluntary uncommitted cost sharing, university faculty effort over and above that which is committed and budgeted for in a sponsored agreement, is not generally captured in the accounting system. Some Federal Government officials have interpreted Circular A-21 to require that a proportionate share of F&A costs be assigned to the voluntary uncommitted cost sharing effort either by including an estimated amount in the organized research base (thereby lowering the F&A reimbursement rate) or by adjusting the allocation of facility costs related to this effort (thereby lowering the facility costs eligible for reimbursement). The burden associated with detailed reporting of voluntary uncommitted cost sharing may be a disincentive for universities to contribute additional time to a research effort. In addition, the imprecise nature of the data concerning the amount of involuntary uncommitted cost sharing has made it difficult to compute and use as part of rate negotiations between the Federal Government and universities. Consequently, the memorandum stated that "voluntary uncommitted cost sharing should be treated differently from committed effort and should not be included in the organized research base for calculating the F&A rate or reflected in any allocation of F&A costs" (Gotbaum 2001).

Circular A-21 states that "the dual role of students engaged in research and the resulting benefits to sponsored agreements are fundamental to the research effort and shall be recognized in the application of these principles." It further states that "tuition remission costs for students are allowable on sponsored awards provided that there is a bona fide employer-employee relationship between the student and the institution." This last statement has been interpreted by some government officials to mean that, for tuition remission costs to be allowable, students must be treated as employees of the university for tax purposes, which would mean that the students' tuition remission benefits must be treated as taxable wages. This misunderstanding generated a considerable amount of concern from universities and Federal research agencies. The OMB memorandum clarified this by indicating that Federal policy on the support of graduate students participating in research is to provide a reasonable amount of support (tuition remission and other support) on the basis of the individual's participation in the project and is not contingent on there being an employer-employee relationship for tax purposes.

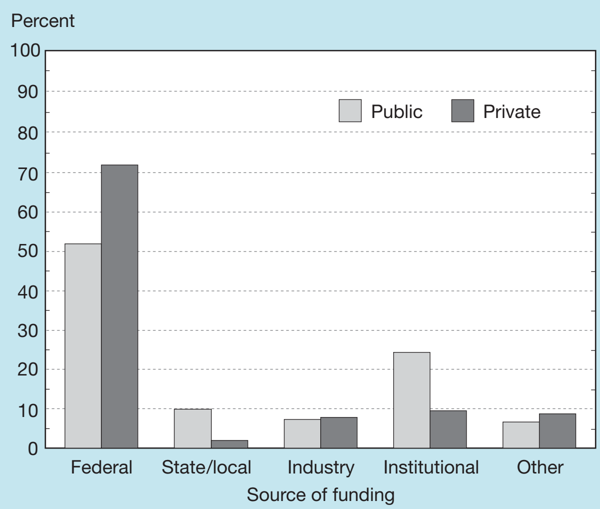
has steadily declined from 1.5 to 1.2 percent. (See appendix table 4-4 for time series data on industry-funded R&D.)

- **Other sources of funds.** In 2000, other sources of support accounted for 7 percent of academic R&D funding, a level that has stayed rather constant during the past three decades after declining from a peak of 10 percent in 1953. This category of funds includes grants for R&D from nonprofit organizations and voluntary health agencies and gifts from private individuals that are restricted by the donor to the conduct of research, as well as all other sources restricted to research purposes not included in the other categories.

Funding by Institution Type

Although public and private universities rely on the same funding sources for their academic R&D, the relative importance of those sources differs substantially for these two types of institutions. (See figure 5-6 and appendix table 5-3.) For all *public* academic institutions combined, slightly less than 10 percent of R&D funding in 1999, the most recent year for which data are available, came from state and local funds, about 24 percent from institutional funds, and about 52 percent from the Federal Government. *Private* academic institutions received a much smaller portion of their funds from state and local governments (about 2 percent) and institutional sources (10 percent), and a much larger share from the Federal Government (72 percent). The large difference in the role of institutional funds at public and private institutions is most likely due to a substantial amount of general-purpose state and local government funds that public institutions receive and decide to use for R&D (although data on such breakdowns are not collected). Both public and private institutions received approximately 7–8 percent of their respective R&D support from industry in 1999. Over the past two decades, the Federal share of support has declined, and the industry and institutional shares have increased for both public and private institutions.

Figure 5-6.
Sources of academic R&D funding for public and private institutions: 1999



See appendix table 5-3. *Science & Engineering Indicators – 2002*

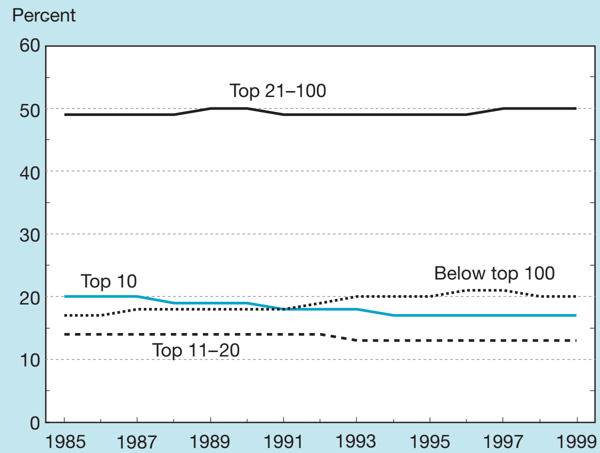
Distribution of R&D Funds Across Academic Institutions

The nature of the distribution of R&D funds across academic institutions has been and continues to be a matter of interest to those concerned with the academic R&D enterprise. Most academic R&D is now, and has been historically, concentrated in relatively few of the 3,600 U.S. institutions of higher education.[7] In fact, if all such institutions were ranked by their 1999 R&D expenditures, the top 200 institutions would account for about 96 percent of R&D expenditures. (See appendix table 5-4.) In 1999:

- the top 10 institutions spent 17 percent of total academic R&D funds ($4.6 billion),
- the top 20 institutions spent 30 percent ($8.3 billion),
- the top 50 spent 57 percent ($15.6 billion), and
- the top 100 spent 80 percent ($22.1 billion).

The historic concentration of academic R&D funds diminished somewhat between the mid-1980s and mid-1990s but has remained relatively steady since then. (See figure 5-7.) In 1985, the top 10 institutions received about 20 percent of the nation's total academic R&D expenditures and the top 11–20 institutions received 14 percent compared with 17 and 13 percent, respectively, in 1999. The composition of the universities in the top 20 has also fluctuated slightly from 1985 to 1999. There was almost no change in the share of the group of institutions ranked 21–100 during this period. The decline in the top 20 institutions' share was matched by the increase in the share of those institutions in the group below the top 100. This group's share increased from 17 to 20 percent of total academic R&D funds, signifying a broadening of the base. See "Spreading Institutional Base of Federally Funded Academic R&D" later in this chapter, under the section "Federal Support of Academic R&D," for a discussion of the increased number of academic institutions receiving Federal support for their R&D activities during the past three decades.

Figure 5-7.
Share of academic R&D of universities and colleges by rank of R&D expenditures: 1985–99



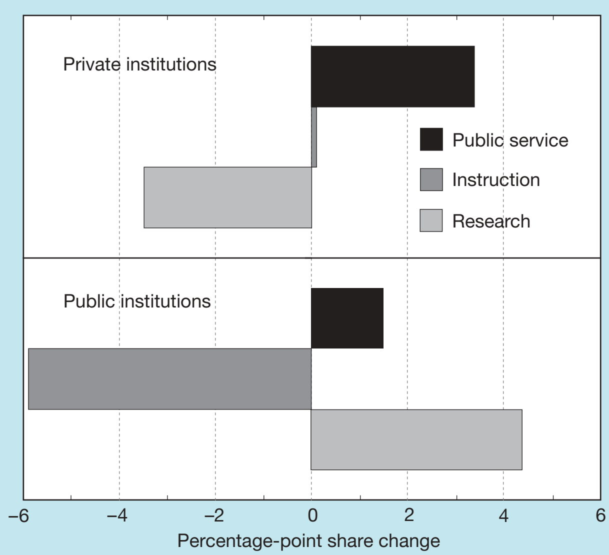
See appendix table 5-4. *Science & Engineering Indicators – 2002*

Emphasis on Research at Universities and Colleges

Between 1977 and 1996, the nation's universities and colleges increased their relative emphasis on research, as measured by research expenditures as a share of combined expenditures on instruction, research, and public service,[8] which are the three primary functions of academic institutions. This indicator rose from 19 to 21 percent during this period. This aggregate change, however, masks quite different trends at public and private institutions and among institutions with different Carnegie classifications. At public universities and colleges, the research expenditure share rose from 17 to 21 percent during this period, whereas at private institutions this share declined from 24 to 21 percent. (See figure 5-8 and appendix table 5-5.) The increased relative emphasis on research activity at public institutions was offset by a decline in emphasis on instruction. At private institutions, the declining relative emphasis on research was not offset by increased emphasis on instruction but by an increased emphasis on public service.

Although the increased emphasis on research in public institutions occurred in each of the four groups of institutions in Carnegie classes Research I and II and Doctorate-granting I and II, and the declining emphasis in research at private

Figure 5-8.
Changes in share of combined expenditures accounted for by research, instruction, and public service at public and private institutions: 1977–96



See appendix table 5-5. *Science & Engineering Indicators – 2002*

[7] The Carnegie Foundation for the Advancement of Teaching classified about 3,600 degree-granting institutions as higher education institutions in 1994. See chapter 2 sidebar, "Carnegie Classification of Academic Institutions," for a brief description of the Carnegie categories. These higher education institutions include four-year colleges and universities, two-year community and junior colleges, and specialized schools such as medical and law schools. Not included in this classification scheme are more than 7,000 other postsecondary institutions (secretarial schools, auto repair schools, etc.).

[8] *Public service* includes funds expended for activities that are established primarily to provide noninstructional services beneficial to individuals and groups external to the institution. These activities include community service programs and cooperative extension services.

institutions occurred in all four of these Carnegie classes, the extent of change was more substantial in some groups than in others. (See figure 5-9 and appendix table 5-6.) The increase in research emphasis in the public Doctorate-granting I group (6 to 13 percent) and the public Doctorate-granting II group (16 to 25 percent) were much larger than for the other two public groups. The decline for the private Research I class (42 to 36 percent) and the private Doctorate-granting II group (18 to 14 percent) were larger than for the other two groups.

Expenditures by Field and Funding Source

The distribution of academic R&D funds across S&E disciplines often is the unplanned result of numerous, sometimes unrelated, decisions and therefore needs to be monitored and documented to ensure that it remains appropriately balanced. The overwhelming share of academic R&D expenditures in 1999 went to the life sciences, which accounted for 57 percent of total academic R&D expenditures, 56 percent of Federal academic R&D expenditures, and 58 percent of non-Federal academic R&D expenditures. (See appendix table 5-7.) Within the life sciences, the medical sciences accounted for 29 percent of total academic R&D expenditures and the biological sciences for 18 percent.[9] The next largest block of total academic R&D expenditures was for engineering—15 percent in 1999. The distribution of Federal and non-Federal funding of academic R&D in 1999 varied by field. (See appendix table 5-7.) For example, the Federal Government supported more than three-quarters of academic R&D expenditures in both physics and atmospheric sciences but one-third or less of academic R&D in economics, political science, and the agricultural sciences.

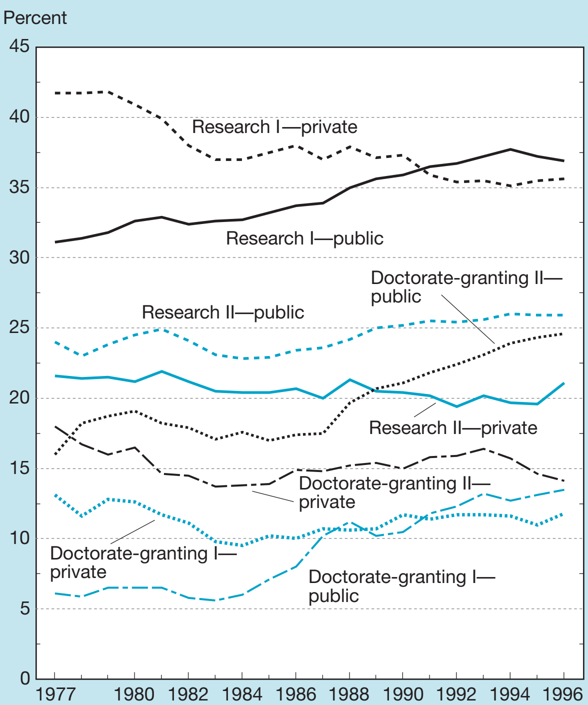
The declining Federal share in support of academic R&D is not limited to particular S&E disciplines. The federally financed fraction of support for *each* of the broad S&E fields was lower in 1999 than in 1973.[10] (See appendix table 5-8.) The most dramatic decline occurred in the social sciences, down from 57 percent in 1973 to 37 percent in 1999. The overall decline in Federal share also holds for all the reported fine S&E fields. However, most of the declines occurred in the 1980s, and most fields did not experience declining Federal shares during the 1990s.

Although academic R&D expenditures in constant 1996 dollars for every field increased between 1973 and 1999 (see figure 5-10 and appendix table 5-9), the R&D emphasis of

[9]The medical sciences include fields such as pharmacy, veterinary medicine, anesthesiology, and pediatrics. The biological sciences include fields such as microbiology, genetics, biometrics, and ecology. These distinctions may be blurred at times, because boundaries between fields often are not well defined.

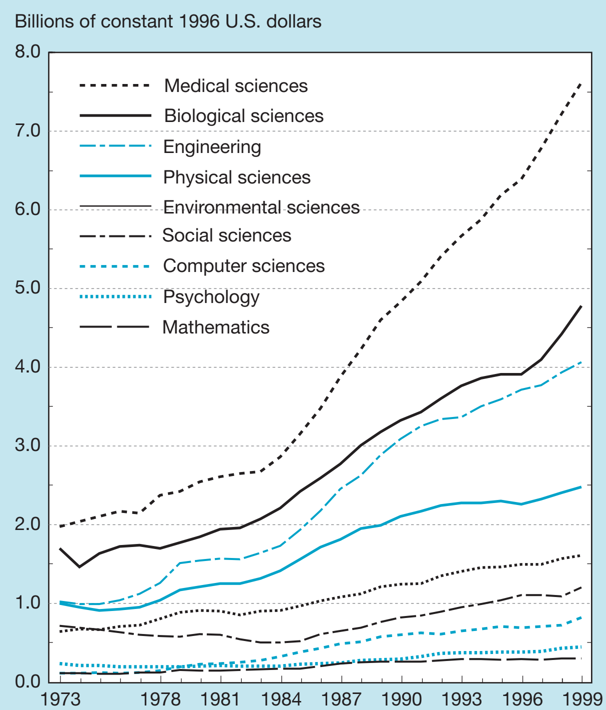
[10]In this chapter, the broad S&E fields refer to the physical sciences, mathematics, computer sciences, environmental sciences (earth, atmospheric, and ocean), life sciences, psychology, social sciences, other sciences (not elsewhere classified), and engineering. The more disaggregated fields of science and engineering are referred to as "fine fields" or "subfields."

Figure 5-9.
Research as percentage of the total of instruction, research, and public service expenditures, by Carnegie class and type of control: 1977–96



See appendix table 5-6. *Science & Engineering Indicators – 2002*

Figure 5-10.
Academic R&D expenditures, by field: 1973–99



NOTE: See appendix table 4-1 for GDP implicit price deflators used to convert current dollars to constant 1996 dollars.

See appendix table 5-9. *Science & Engineering Indicators – 2002*

the academic sector, as measured by its S&E field shares, changed during this period.[11] (See figure 5-11.) Absolute shares of academic R&D have:

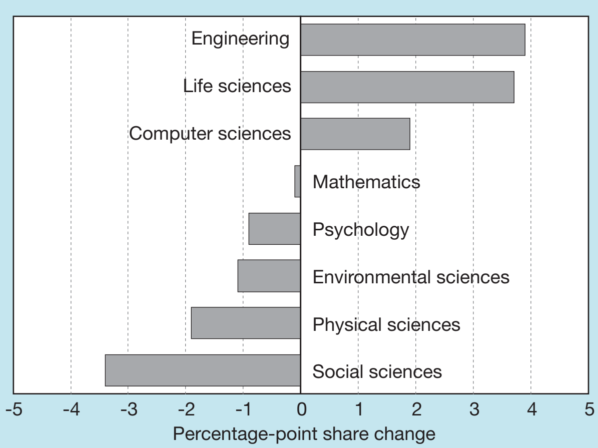
- increased for engineering, the life sciences, and the computer sciences;
- remained roughly constant for mathematics; and
- declined for psychology, environmental (earth, atmospheric, and ocean) sciences, physical sciences, and social sciences.

Although the proportion of the total academic R&D funds going to the life sciences increased by only 4 percentage points between 1973 and 1999, rising from 53 to 57 percent of academic R&D, the medical sciences' share increased by almost 7 percentage points, from 22 to 29 percent of academic R&D, during this period. (See appendix table 5-9.) The share of funds for each of the other two major components of the life sciences, agricultural sciences and biological sciences, decreased during the period. Engineering's share increased by almost 4 percentage points, from about 11.5 to 15.5 percent of academic R&D, while computer sciences' share increased by 2 percentage points, from 1 to 3 percent.

The social sciences' proportion of total academic R&D funds declined by more than 3 percentage points (from 8 to less than 5 percent) between 1973 and 1999. Within the social sciences, R&D shares for each of the three main fields, economics, political science, and sociology, declined over the period. Psychology's share declined by 1 percentage point (from 3 to 2 percent of academic R&D). The environmental sciences' share also declined by 1 percentage point (from 7 to 6 percent). Within the environmental sciences, the three major fields; atmospheric, earth, and ocean sciences, each experienced a decline in share. The physical sciences' share also declined during this period, from 11 to 9 percent. Within the physical sciences, however, astronomy's share increased, while the shares of both physics and chemistry declined.

[11]For a more detailed discussion of these changes, see *How Has the Field Mix of Academic R&D Changed?* (NSF 1998) and *Trends in Federal Support of Research and Graduate Education* (National Academies Board on Science, Technology and Economic Policy, forthcoming).

Figure 5-11.
Changes in share of academic R&D in selected S&E fields: 1973–99



See appendix table 5-9. *Science & Engineering Indicators – 2002*

Federal Support of Academic R&D

The Federal Government continues to provide the majority of the funding for academic R&D. Its overall contribution is the combined result of a complex set of Executive and Legislative branch decisions to fund a number of key R&D-supporting agencies with differing missions.

Some of the Federal R&D funds obligated to universities and colleges are the result of appropriations that Congress directs Federal agencies to award to projects that involve specific institutions. These funds are known as congressional earmarks. (See sidebar, "Congressional Earmarking to Universities and Colleges" for a discussion of this subject.) Examining and documenting the funding patterns of the key funding agencies is key to understanding both their roles and that of the government overall.

Top Agency Supporters

Three agencies are responsible for most of the Federal obligations for academic R&D are concentrated in three agencies: the National Institutes of Health (NIH), NSF, and the Department of Defense (DOD). (See appendix table 5-10.) Together, these agencies are estimated to have provided approximately 84 percent of total Federal financing of academic R&D in 2001: 60 percent by NIH, 15 percent by NSF, and 9 percent by DOD. An additional 11 percent of the 2001 obligations for academic R&D are estimated to be provided by the National Aeronautics and Space Administration (NASA) at 4 percent; the Department of Energy (DOE) at 4 percent; and the Department of Agriculture (USDA) at 3 percent. Federal obligations for academic research are concentrated similarly as those for R&D. (See appendix table 5-11.) Some differences exist, however, because some agencies (e.g., DOD) place greater emphasis on development, whereas others (e.g., NSF) place greater emphasis on research.

Between 1990 and 2001, NIH's funding of academic R&D increased most rapidly, with an estimated average annual growth rate of 4.9 percent per year in constant 1996 dollars. NSF and NASA experienced the next highest rates of growth: 4.2 and 3.1 percent, respectively.

Agency Support by Field

Federal agencies emphasize different S&E fields in their funding of academic research. Several agencies concentrate their funding in one field; the Department of Health and Human Services (HHS) and USDA focus on life sciences, whereas DOE concentrates on physical sciences. Other agen-

Congressional Earmarking to Universities and Colleges

Academic earmarking, the congressional practice of providing Federal funds to educational institutions for research facilities or projects without merit-based peer review, exceeded the billion-dollar mark for the first time ever in fiscal year (FY) 2000 and reached almost $1.7 billion in FY 2001.*

The lack of an accepted definition of academic earmarking, combined with the difficulty of detecting many earmarked projects because they are either obscured or described vaguely in the legislation providing the funding, often makes it difficult to obtain exact figures for either the amount of funds or the number of projects specifically earmarked for universities and colleges. Even with these difficulties, however, a number of efforts have been undertaken during the past two decades to measure the extent of this activity.†

A report from the Committee on Science, Space, and Technology (U.S. House of Representatives 1993) that estimates trends in congressional earmarking indicated that the dollar amount of such earmarks increased from the tens to the hundreds of millions between 1980 and the early 1990s, reaching $708 million in 1992. (See text table 5-2.) In the report, the late Congressman George E. Brown, Jr., (D-CA) stated, "I believe that the rational, fair, and equitable allocation and oversight of funds in support of the nation's research and development enterprise is threatened by the continued increase in academic earmarks. To put it colloquially, a little may be okay, but too much is too much."

During the past decade, the *Chronicle of Higher Education* also tried to estimate trends in academic earmarking through its annual survey of Federal spending laws and the congressional reports that explain them. The *Chronicle's* latest analysis showed that after reaching a peak of $763 million in 1993, earmarked funds declined rather substantially over the next several years, reaching a low of $296 million in FY 1996. After 1996, however, earmarks began to increase once again, and this growth continued throughout the latter part of the 1990s. Congress directed Federal agencies to award at least $1.044 billion for such projects in FY 2000, a 31 percent rise over FY 1999's record total of $797 million (Brainard and Southwick 2000), and $1.668 billion in FY 2001, a 60 percent rise over FY 2000 (Brainard and Southwick 2001). A record number of new institutions received earmarks in FY 2000, and money was provided for institutions in every state except Delaware. Also, for the first time, Congress earmarked funds to a virtual university. Helping to drive the large increase in FY 2000 was a sharp rise in earmarks for construction projects, with more than $152 million being spent on brick-and-mortar projects on campuses, more than double the amount spent in FY 1999.

Text table 5-2.
Funds for Congressionally earmarked academic research projects: 1980–2001
(Millions of dollars)

Year	Earmarked funds	Year	Earmarked funds
1980	11	1991	470
1981	0	1992	708
1982	9	1993	763
1983	77	1994	651
1984	39	1995	600
1985	104	1996	296
1986	111	1997	440
1987	163	1998	528
1988	232	1999	797
1989	299	2000	1,044
1990	248	2001	1,668

SOURCES: Data for 1980–92 are from the U.S. House of Representatives, Committee on Science, Space, and Technology, 1993; "Academic Earmarks: An Interim Report by the Chairman of the Committee on Science, Space, and Technology" (Washington, DC); data from 1993–2000 are from J. Brainard and R. Southwick, "Congress Gives Colleges a Billion-Dollar Bonanza in Earmarked Projects" (*The Chronicle of Higher Education,* Volume 46, July 28, 2000, p. A29); and data from 2001 are from J. Brainard and R. Southwick, "A Record Year at the Federal Trough: Colleges Feast on $1.67 Billion in Earmarks" (*The Chronicle of Higher Education,* Volume 47, August 10, 2001, p. A20).

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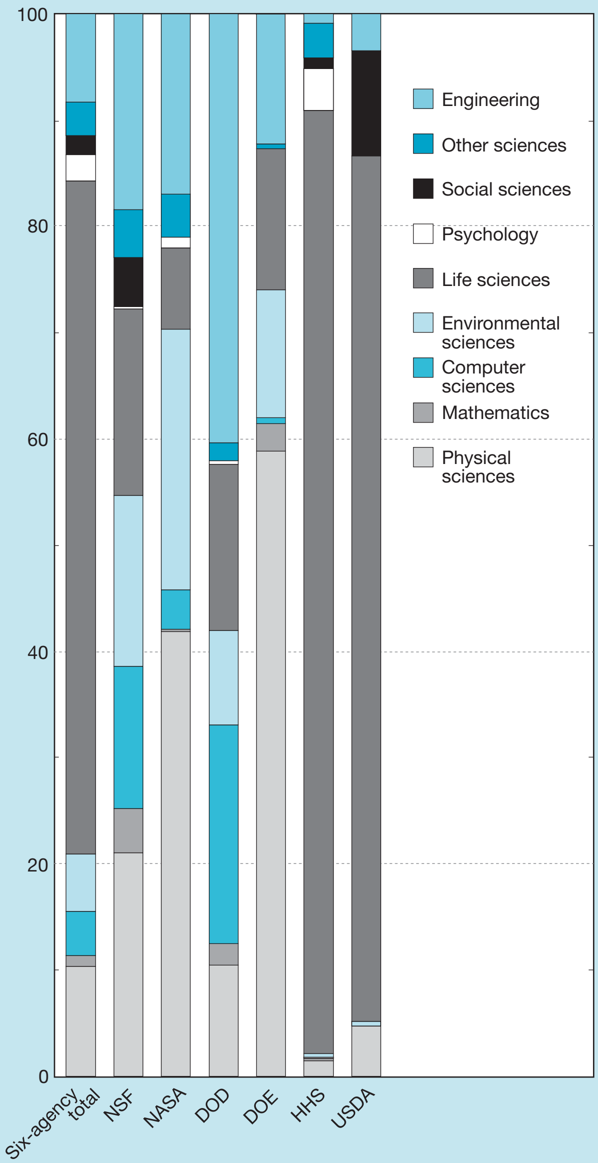
* Not all of these funds go to projects that involve research. In FY 2001, an estimated 84 percent of the earmarked funds were for research projects, research equipment, or construction or renovation of research laboratories.

† In its FY 2001 budget submission to Congress (OMB 2001), OMB included a new category of Federal funding for research: research performed at congressional direction. This consists of intramural and extramural research in which funded activities are awarded to a single performer or collection of performers. There is limited or no competitive selection, or there is competitive selection but the research is outside the agency's primary mission, and undertaking the research is based on direction from the Congress in law, in report language, or by other direction. The total reported for this activity is $2.2 billion. The data are not disaggregated by type of performer.

Figure 5-12.
Distribution of Federal agency academic research obligations, by field: FY 1999



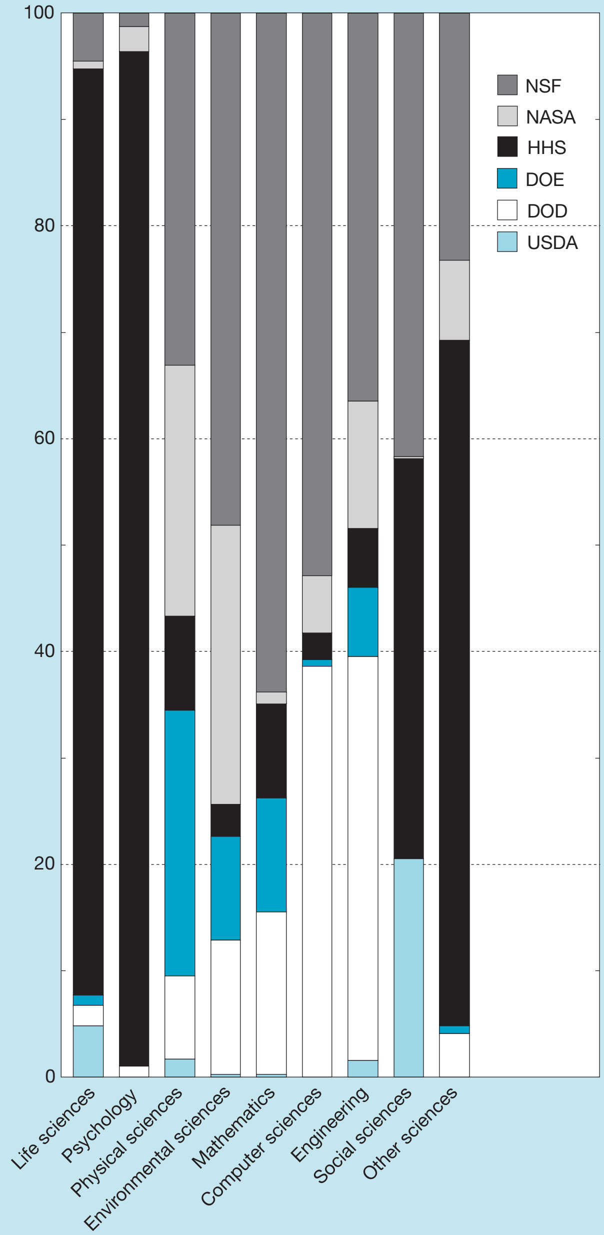
NSF = National Science Foundation; NASA = National Aeronautics and Space Administration; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; USDA = Department of Agriculture

NOTE: Agencies reported represent approximately 97 percent of Federal academic research obligations.

See appendix table 5-12. *Science & Engineering Indicators – 2002*

cies, NSF, NASA, and DOD, have more diversified funding patterns. (See figure 5-12 and appendix table 5-12.) Even though an agency may place a large share of its funds in one field, it may not be a leading contributor to that field, particularly if it does not spend much on academic research. (See figure 5-13.) In FY 1999, NSF was the lead funding agency in physical sciences (33 percent of total funding), mathematics (64 percent), computer sciences (53 percent), environmental sciences (48 percent), and social sciences (42 percent). DOD was the lead funding agency in engineering (38 percent). HHS was the lead funding agency in life sciences (87 percent) and psychology (95 percent). Within the fine S&E

Figure 5-13.
Major agency field shares of Federal academic research obligations: FY 1999



NSF = National Science Foundation; NASA = National Aeronautics and Space Administration; HHS = Department of Health and Human Services; DOE = Department of Energy; DOD = Department of Defense; USDA = United States Department of Agriculture

NOTE: Agencies reported represent approximately 97 percent of Federal academic research obligations.

See appendix table 5-13. *Science & Engineering Indicators – 2002*

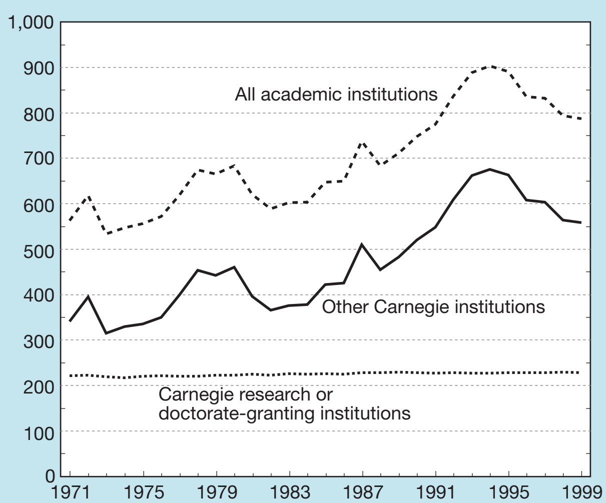
fields, other agencies took the leading role: DOE in physics (44 percent), USDA in agricultural sciences (100 percent), and NASA in astronomy (78 percent) and both aeronautical (55 percent) and astronautical (97 percent) engineering. (See appendix table 5-13.)

Spreading Institutional Base of Federally Funded Academic R&D

Since 1994, the number of academic institutions receiving Federal support for their R&D activities has declined. This decline followed a 20-year period in which there was a general upward trend in the number of institutions receiving such support.[12] (See figure 5-14.) The change in number has occurred almost exclusively among institutions of higher education not classified as Carnegie research or doctorate-granting institutions but in those classified as comprehensive; liberal arts; two-year community, junior, and technical; or professional and other specialized schools. The number of such institutions receiving Federal support nearly doubled between 1971 and 1994, rising from 341 to 676, but then dropped to only 559 in 1999. (See appendix table 5-14.) The institutions that were not classified as Carnegie research or doctorate-granting institutions also received a larger share of the reported Federal obligations for R&D to universities and colleges in the 1990s than they have at any time in the past. Their share even continued to increase during the latter part of the 1990s, reaching almost 14 percent in 1999. The largest percentage this group had received before the 1990s was just under 11 percent in 1977. This increase in share is consistent with the increase in the share of academic R&D going to institutions below the top 100 reported earlier in this chapter in "Distribution of R&D Funds Across Academic Institutions."

[12]Although there was a general increase in the number of institutions receiving Federal R&D support between 1974 and 1994, a rather large decline occurred in the early 1980s that was most likely due to the fall in Federal R&D funding for the social sciences during that period.

Figure 5-14.
Number of academic institutions receiving Federal R&D support by selected Carnegie classifications: 1971–99



NOTES: See "Carnegie Classification of Academic Institutions," in chapter 2 for information on the institutional categories used by the Carnegie Foundation for the Advancement of Teaching. "Other Carnegie institutions" are all institutions except Carnegie research and doctorate-granting institutions.

See appendix table 5-14. *Science & Engineering Indicators – 2002*

Academic R&D Facilities and Equipment

The condition of the physical infrastructure for academic R&D, especially the state of research facilities and equipment, is a key factor in the continued success of the U.S. academic R&D enterprise. The National Science Board's (NSB's) concern that the quality and adequacy of the S&E infrastructure are critical to maintaining U.S. leadership in S&E research and education recently led it to establish a task force to examine this issue. (See sidebar, "The NSB Task Force on S&E Infrastructure.")

Facilities

Total Space. The amount of academic S&E research space[13] grew continuously over the past decade. Between 1988 and 1999, total academic S&E research space increased by almost 35 percent, from about 112 million to 151 million net assignable square feet (NASF).[14] (See appendix table 5-15.) Doctorate-granting institutions accounted for most of the growth in research space over this period.

Little change was noted in the distribution of academic research space across S&E fields between 1988 and 1999. (See appendix table 5-15.) About 90 percent of current academic research space continues to be concentrated in six S&E fields:

- ♦ biological sciences (21 percent in 1988 and 1999),
- ♦ medical sciences (17 percent in 1988 and 18 percent in 1999),
- ♦ agricultural sciences (16 percent in 1988 and 17 percent in 1999),
- ♦ engineering (14 percent in 1988 and 17 percent in 1999),
- ♦ physical sciences (14 percent in 1988 and 13 percent in 1999), and
- ♦ environmental sciences (5 percent in 1988 and 1999).

New Construction. Between 1986–87 and 1998–99, the total anticipated cost for completion of new construction projects for academic research facilities begun in each two-year period fluctuated between $2 and $3 billion. (See appendix table 5-16.) Projects planned for 2000 and 2001, however, are expected to cost $7.4 billion by the time they are completed, and those begun in 1998 and 1999 are expected to cost $2.8 billion (reported in 1999 survey). Earlier in the planning

[13] For more detailed data and analysis on academic S&E research facilities (e.g., by institution type and control), see NSF (2001d,e).

[14] "Research space" here refers to NASF within facilities (buildings) in which S&E research activities take place. NASF is defined as the sum of all areas (in square feet) on all floors of a building assigned to, or available to be assigned to, an occupant for a specific use, such as instruction or research. Multipurpose space within facilities (e.g., an office) is prorated to reflect the proportion of use devoted to research activities. NASF data for new construction and repair/renovation are reported for combined years (e.g., 1987–88 data are for FY 1987 and FY 1988). NASF data on total space are reported at the time of the survey and were not collected in 1986.

stage, however, projects expected to begin in 1998 and 1999 were expected to cost $3.9 billion (reported in the previous S&E Facilities survey). Construction projects initiated between 1986 and 1999 were expected to produce more than 72 million square feet of research space when completed, the equivalent of about 48 percent of estimated 1999 research space. A significant portion of newly created research space is likely to replace obsolete or inadequate space rather than actually increase existing space, indicated by the total research space increase of 39 million NASF between 1988–89 and 1999, a period in which new construction activity was expected to produce 62 million NASF. (See appendix table 5-15.)

The ratio of planned new construction during the 1986–99 period to 1999 research space differs across S&E fields. More than three-quarters of the research space in medical sciences at medical schools and in computer sciences appears to have been built in the 1986–99 period. In contrast, less than one-quarter of the research space for mathematics and psychology appears to have been newly constructed during this period. (See figure 5-15.)

Repair and Renovation. The total cost of repair/renovation projects has also fluctuated over time. Expenditures for major repair/renovation (i.e., projects costing more than $100,000) of academic research facilities begun in 1998–99 are expected to reach $1.7 billion. (See appendix table 5-16.) Projects initiated between 1986 and 1999 were expected to result in the repair/renovation of more than 87 million square feet of research space.[15] (See appendix table 5-15.) Repair/renovation expenditures as a proportion of total capital expenditures (construction and repair/renovation) have increased

The NSB Task Force on S&E Infrastructure

The National Science Board is responsible for monitoring the health of the national research and education enterprise. Within the past year, NSB determined that the status of the national infrastructure for fundamental science and engineering should be assessed to ensure its future quality and availability to the broad S&E community. The Board believed that the S&E infrastructure had grown and changed and that the needs of the S&E community had evolved since the last major assessments were conducted more than a decade ago. Several trends contributed to the need for a new assessment, including:

- the impact of new technologies on research facilities and equipment;
- changing infrastructure needs in the context of new discoveries, intellectual challenges, and opportunities;
- the impact of new tools and capabilities such as information technology and large databases;
- the rapidly escalating cost of research facilities;
- changes in the university environment affecting support for S&E infrastructure development and operation; and
- the need for new strategies for partnering and collaboration.

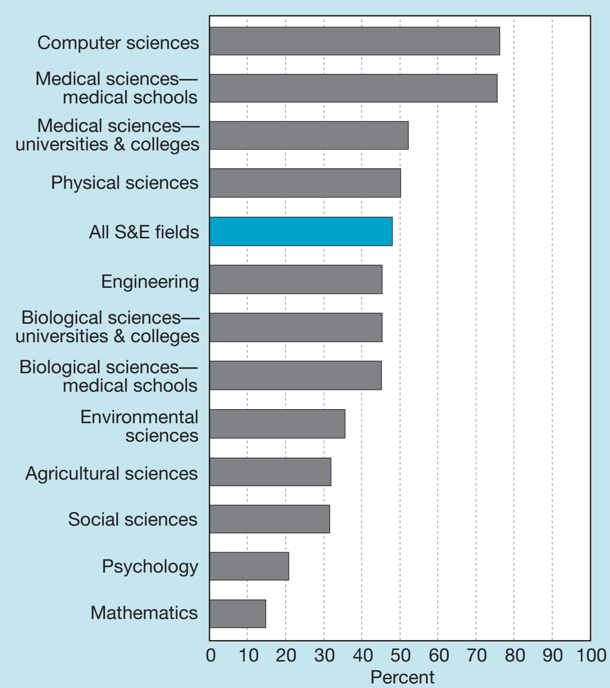
An NSB Task Force on S&E Infrastructure was established to undertake and guide the assessment. The task force was asked to assess the current status of the national S&E infrastructure, the changing needs of science and engineering, and the requirements for a capability of appropriate quality and size to ensure continuing U.S. leadership. Among the specific issues the task force was asked to consider were the following:

- appropriate strategies for sharing infrastructure costs for both development and operations among different sectors, communities, and nations;
- partnering and use arrangements conducive to ensuring the most effective use of limited resources and the advancement of discovery;
- the balance between maintaining the quality of existing facilities and the creation of new ones; and
- the process for establishing priorities for investment in infrastructure across fields, sectors, and Federal agencies.

Further information about the work of the task force can be found on the Board's website at <http://www.nsf.gov/nsb/>.

[15] It is difficult to report repaired/renovated space in terms of a percentage of existing research space. As collected, the data do not differentiate between repair and renovation, nor do they provide an actual count of unique square footage that has been repaired or renovated. Thus, any proportional presentation might include double or triple counts, because the same space could be repaired (especially) or renovated several times.

Figure 5-15.
New construction of research space planned during the 1986–99 period as a percentage of 1999 research space, by S&E field



See appendix table 5-15. *Science & Engineering Indicators – 2002*

steadily since 1990–91, rising from 22 percent of all capital project spending to 37 percent by 1998–99.

Sources of Funds. Academic institutions derive their funds for new construction and repair/renovation of research facilities from a number of sources: the Federal Government, state and local governments, institutional funds, private donations, tax-exempt bonds, other debt sources, and other sources. (See appendix tables 5-17 and 5-18.) In most years, state and local governments have provided a larger share of support than either private donations or tax-exempt bonds, followed by institutional funds. The Federal Government has never provided more than 14.1 percent of the funds for construction and repair/renovation. In 1998–99, the latest year for which data are available:

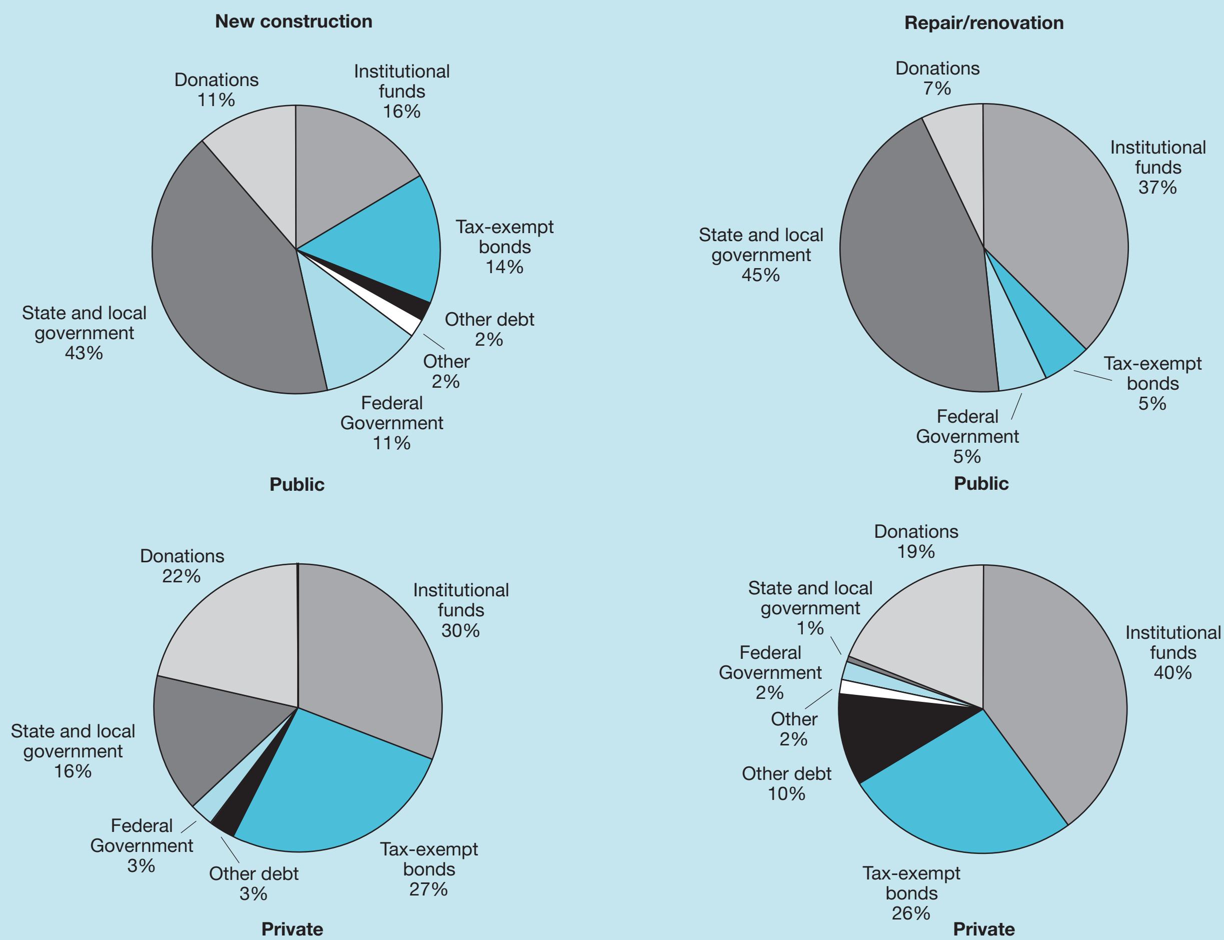
- the Federal Government directly accounted for only 8 percent of all construction funds and 4 percent of repair/renovation funds,[16]
- state and local governments accounted for 32 percent of all construction funds and 26 percent of repair/renovation funds,
- private donations accounted for 15 percent of all construction funds and 12 percent of repair/renovation funds,
- institutional funds accounted for 22 percent of all construction funds and 38 percent of repair/renovation funds, and
- tax-exempt bonds accounted for 19 percent of all construction funds and 14 percent of repair/renovation funds.

Public and private institutions drew on substantially different sources to fund the construction and repair/renovation of research space. (See figure 5-16) Public institutions relied primarily on:

- state and local governments (43 percent of funds for new construction and 45 percent of funds for repair/renovation),
- private donations (11 percent of funds for new construction and 7 percent of funds for repair/renovation),
- institutional funds (16 percent of funds for new construction and 37 percent of funds for repair/renovation), and

[16] Some additional Federal funding comes through overhead on grants and/or contracts from the Federal Government. These indirect cost payments are used to defray the overhead costs of conducting federally funded research and are reported as institutional funding on the NSF facilities survey. See the sidebar, "Recent Developments on the Indirect Cost Front," earlier in this chapter.

Figure 5-16.
Sources of funds for new construction and repair/renovation of research facilities at public and private universities and colleges: 1999



NOTE: Shares may not add to 100 percent because of rounding.

See appendix tables 5-17 and 5-18.

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- ♦ tax-exempt bonds (15 percent of funds for new construction and 5 percent of funds for repair/renovation).

Private institutions relied primarily on:

- ♦ private donations (22 percent of funds for new construction and 19 percent of funds for repair/renovation),
- ♦ institutional funds (30 percent of funds for new construction and 40 percent of funds for repair/renovation), and
- ♦ tax-exempt bonds (27 percent of funds for new construction and 26 percent for repair/renovation).

Adequacy and Condition. Of the institutions reporting research space in 1999, more than 30 percent reported needing additional space in biological sciences in universities and colleges (as opposed to medical schools), physical sciences, psychology, and computer sciences. In all four of these fields, more than 25 percent of these institutions reported needing additional space equal to more than 25 percent of their current research space. (See text table 5-3.) Less than 20 percent of the institutions reported needing any additional space in medical sciences in both medical schools and universities and colleges, in biological sciences in medical schools, and in agricultural sciences.

Survey respondents also rated the condition of their research space in 1999. Slightly more than 40 percent of S&E research space was rated as "suitable for the most scientifically competitive research." (See text table 5-4.) However, 20 percent of the research space was designated as needing major repair/renovation and an additional 6 percent as needing replacement. The condition of this space differs across S&E fields. Fields with the largest proportion of research space needing major repair/renovation or replacement include agricultural sciences (33 percent), environmental sciences, biological sciences in universities and colleges, medical sciences in universities and colleges, and medical sciences in medical schools (each with between 26 and 28 percent).

Unmet Needs. Determining what universities and colleges need for S&E research space is a complex matter. To attempt to measure "real" as opposed to "speculative" needs, the survey asked respondents to report whether there was an approved institutional plan that included any deferred space needing new construction or repair/renovation.[17] Respondents were then asked to estimate, for each S&E field, the costs of such construction and repair/renovation projects and, separately, the costs for similar projects not included in an approved institutional plan.

In 1999, 44 percent of the institutions reported the existence of institutional plans that included deferred capital projects to construct or repair/renovate academic S&E research facilities. Twenty-five percent of institutions reported deferred projects not included in institutional plans. The total estimated cost for all deferred S&E construction and repair/renovation projects (whether included in an institutional plan or not) was $13.6 billion in 1999. Deferred construction projects accounted for 65 percent of this cost and deferred repair/renovation projects for the remaining 35 percent.

Deferred construction costs were close to or exceeded $1 billion in three fields: medical sciences in medical schools, biological sciences in universities and colleges, and engineering. Institutions reported deferred repair/renovation costs in excess of $500 million in the same three fields and in one additional field, as follows: medical sciences in medical

[17] Four criteria are used to define deferred space in a survey cycle: (1) the space must be necessary to meet the critical needs of current faculty or programs; (2) construction must not have been scheduled to begin during the two fiscal years covered by the survey; (3) construction must not have funding set aside for it; and (4) the space must not be for developing new programs or expanding the number of faculty positions.

Text table 5-3.
Adequacy of the amount of S&E research space, by field: 1999

Field	Percentage of institutions needing additional space: Less than 10 percent of current space	10–25 percent of current space	More than 25 percent of current space
Physical sciences	5.0	10.7	27.6
Mathematics	1.5	2.5	17.2
Computer sciences	0.6	3.6	28.4
Environmental sciences	3.9	5.2	18.2
Agricultural sciences	2.4	2.2	4.4
Biological sciences: universities and colleges	5.8	10.4	32.7
Biological sciences: medical schools	1.8	2.9	8.3
Medical sciences: universities and colleges	2.1	4.0	13.5
Medical sciences: medical schools	0.9	4.1	10.3
Psychology	2.4	6.9	25.8
Social sciences	3.6	4.5	19.8
Other sciences	1.5	0.3	1.6
Engineering	5.3	5.8	18.2

SOURCE: National Science Foundation, Division of Science Resources Studies (NSF/SRS), *Science and Engineering Research Facilities: 1999*, NSF 01-330 (Arlington, VA, 2001).

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Text table 5-4.
Condition of academic S&E research facilities, by field: 1999
(Percentage of S&E research space)

Field	Suitable for use in the most scientifically competitive research	Suitable for most levels of research	Requires major repair/renovation to be used effectively	Requires replacement
All S&E	40.9	33.2	19.7	6.2
Physical sciences	40.5	35.7	19.2	4.6
Mathematics	52.4	32.9	11.7	3.1
Computer sciences	42.7	34.7	15.4	7.2
Environmental sciences	38.7	34.2	21.0	6.0
Agricultural sciences	32.6	34.4	23.0	10.1
Biological sciences: universities and colleges	41.2	30.4	22.2	6.2
Biological sciences: medical schools	47.9	28.5	17.5	6.1
Medical sciences: universities and colleges	31.1	42.6	20.0	6.3
Medical sciences: medical schools	43.7	28.3	21.4	6.6
Psychology	38.5	38.7	18.6	4.2
Social sciences	43.3	38.5	14.7	3.4
Engineering	43.1	35.1	17.0	4.8

NOTE: Components may not add to 100 percent because of rounding. Quality was assessed relative to current research program.

SOURCE: National Science Foundation, Division of Science Resources Studies (NSF/SRS), *Scientific and Engineering Research Facilities: 1999*, NSF 01-330 (Arlington, VA, 2001).

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schools ($1.6 billion for construction and 0.5 billion for repair/renovation); biological sciences in universities and colleges ($1.5 billion for construction and $0.7 billion for repair/renovation); engineering ($1.0 billion for construction and $0.8 billion for repair/renovation); and physical sciences ($0.7 billion for construction and $1.0 billion for repair/renovation). (See appendix table 5-19.)

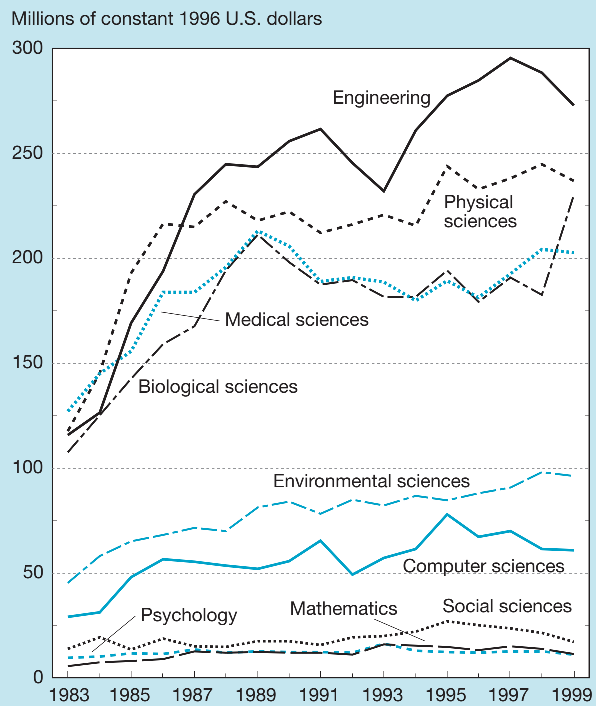
Equipment

Expenditures. In 1999, slightly more than $1.3 billion in current funds was spent for academic research equipment. About 80 percent of these expenditures were concentrated in three fields: life sciences (41 percent), engineering (22 percent), and physical sciences (19 percent). (See figure 5-17 and appendix table 5-20.)

Current fund expenditures for academic research equipment grew at an average annual rate of 4.2 percent (in constant 1996 dollars) between 1983 and 1999. Average annual growth, however, was much higher during the 1980s (8.7 percent) than it was during the 1990s (0.8 percent). The growth patterns in S&E fields varied during this period. For example, equipment expenditures for engineering (5.5 percent) grew more rapidly during the 1983–99 period than did those for the social sciences (1.4 percent) and psychology (1 percent).

Federal Funding. Federal funds for research equipment are generally received either as part of research grants, thus enabling the research to be performed, or as separate equipment grants, depending on the funding policies of the particular Federal agencies involved. The importance of Federal funding for research equipment varies by field. In 1999, the social sciences received slightly less than 40 per-

Figure 5-17.
Current fund expenditures for research equipment at academic institutions, by field: 1983–99



NOTE: See appendix table 4-1 for GDP implicit price deflators used to convert current dollars to constant 1996 dollars.

See appendix table 5-20. *Science & Engineering Indicators – 2002*

cent of their research equipment funds from the Federal Government; in contrast, Federal support accounted for more than two-thirds of equipment funding in the physical sciences, computer sciences, and environmental sciences. (See appendix table 5-21.)

The share of research equipment expenditures funded by the Federal Government declined from 62 to 58 percent between 1983 and 1999, although not steadily. This overall pattern masks different trends in individual S&E fields. For example, the share funded by the Federal Government actually rose during this period for both the social and the environmental sciences.

R&D Equipment Intensity. R&D equipment intensity is the percentage of total annual R&D expenditures from current funds devoted to research equipment. This proportion was lower in 1999 (5 percent) than it was in 1983 (6 percent), although it peaked in 1986 (7 percent). (See appendix table 5-22.) R&D equipment intensity varies across S&E fields. It tends to be higher in physical sciences (about 10 percent in 1999) and lower in social sciences (1 percent) and psychology (2 percent). For the two latter fields, these differences may reflect the use of less equipment, less expensive equipment, or both.

Doctoral Scientists and Engineers in Academia

U.S. universities and colleges are central to the nation's scientific and technological prowess. They generate new knowledge and ideas that form the basis of innovation that is vital to the advancement of science. In the process, they produce the highly trained talent needed to exploit and refresh this new knowledge. In addition, academia increasingly plays an active part in the generation and exploitation of new products, technologies, and processes.

The confluence of these key functions: the pursuit of new knowledge, the training of the people in whom it is embodied, and its exploitation toward generating innovation, makes academia a national resource whose vitality rests in the scientists and engineers who work there. Especially important are those with doctoral degrees who do the research, teach and train the students, and stimulate or help to produce innovation. Who are they, how are they distributed, what do they do, how are they supported, and what do they produce?[18]

Employment and research activity at the 125 largest research-performing universities in the United States are a special focus of analysis.[19] These institutions have a disproportionate influence on the nation's academic science, engineering, and R&D enterprise. They enroll 22 percent of full-time undergraduates and award one-third of all bachelors' degrees, but 40 percent of those in S&E; their baccalaureates, in turn, are the source of 54 percent of the nation's S&E doctoral degree-holders and more than 60 percent of those in academia with R&D as their primary work function. Their influence on academic R&D is even larger: they conduct more than 80 percent of it (as measured by expenditures), and they produce the bulk of academic article outputs and academic patents. For these reasons, they merit special attention.

Growth in academic employment over the past half century reflected both the need for teachers, driven by increasing enrollments, and an expanding research function, largely supported by Federal funds. Trends in indicators relating to research funding have been presented above, this section presents indicators about academic personnel. Because of the intertwined nature of academic teaching and research, much of the discussion deals with the overall academic employment of doctoral-level scientists and engineers, specifically the relative balance between faculty and nonfaculty positions, demographic composition, faculty age structure, hiring of new Ph.D.s, trends in work activities, and trends in Federal support. The section also includes a discussion of different estimates of the nation's academic R&D workforce and effort and considers whether a shift away from basic research toward more applied R&D functions has occurred.

Academic Employment of Doctoral Scientists and Engineers

Universities and colleges employ less than half of doctoral scientists and engineers.[20] Academic employment of S&E doctorate holders reached a record high of 240,200 in 1999, approximately twice their number in 1973. Long-term growth of these positions was markedly slower than that in business, government, and other segments of the economy. The academic doubling compares with increases of 230 percent for private companies, 170 percent for government, and 190 percent for all other segments. As a result, the academic employment share dropped from 55 to 45 percent during the 1973–99 period.

Within academia, growth was slowest for the major research universities. Text table 5-5 shows average annual growth rates for S&E Ph.D.-holders in various segments of the U.S. economy; appendix table 5-23 breaks down academic employment by type of institution.

Foreign-Born Academic Scientists and Engineers

An increasing number (nearly 30 percent) of Ph.D.-level scientists and engineers at U.S. universities and colleges are foreign-born. Like other sectors of the economy, academia has long relied extensively on foreign talent among its faculty, students, and other professional employees; this reliance increased during the 1990s. By a conservative estimate, for-

[18] The academic doctoral S&E workforce includes full and associate professors (referred to as "senior faculty"); assistant professors and instructors (referred to as "junior faculty"); and lecturers, adjunct faculty, research and teaching associates, administrators, and postdoctorates. S&E fields are defined by field of Ph.D. degree. All numbers are estimates rounded to the nearest 100. The reader is cautioned that small estimates may be unreliable.

[19] This set of institutions comprises the Carnegie Research I and II universities, based on the following 1994 classification: institutions with a full range of baccalaureate programs, commitment to graduate education through the doctorate, annual award of at least 50 doctoral degrees, and receipt of Federal support of at least $15.5 million (1989–91 average); see Carnegie Foundation for the Advancement of Teaching (1994). The classification has since been modified, but the older schema is more appropriate to the discussion presented here.

[20] Unless specifically noted, data on doctoral scientists and engineers refer to persons with doctorates from U.S. institutions, surveyed biannually by NSF in the *Survey of Doctorate Recipients.*